



## ■ GENERAL ORTHOPAEDICS

# Optimization of tissue adhesive curing time for surgical wound closure

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## Aims

Tissue adhesives (TAs) are a commonly used adjunct to traditional surgical wound closures. However, TAs must be allowed to dry before application of a surgical dressing, increasing operating time and reducing intraoperative efficiency. The goal of this study is to identify a practical method for decreasing the curing time for TAs.

## Methods

Six techniques were tested to determine which one resulted in the quickest drying time for 2-octyle cyanoacrylate (Dermabond) skin adhesive. These were nothing (control), fanning with a hand (Fanning), covering with a hand (Covering), bringing operating room lights close (OR Lights), ultraviolet lights (UV Light), or prewarming the TA applicator in a hot water bath (Hot Water Bath). Equal amounts of TA were applied to a reproducible plexiglass surface and allowed to dry while undergoing one of the six techniques. The time to complete dryness was recorded for ten specimens for each of the six techniques.

## Results

Use of the Covering, OR Lights, and Hot Water Bath techniques were associated with a 25- ( $p = 0.042$ ), 27- ( $p = 0.023$ ), and 30-second ( $p = 0.009$ ) reduction in drying time, respectively, when compared to controls. The UV Light ( $p = 0.404$ ) and Fanning ( $p = 1.000$ ) methods had no effect on drying time.

## Conclusion

Use of the Covering, OR Lights, and Hot Water Bath techniques present a means for reducing overall operating time for surgeons using TA for closure augmentation, which can increase intraoperative efficiency. Further studies are needed to validate this in vivo.

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## Introduction

Tissue adhesives (TAs) are commonly used for both tissue approximation and protection of surgical wounds in all areas of orthopaedic surgery.<sup>1-3</sup> TAs have been shown to safely and effectively diminish postoperative wound drainage.<sup>4</sup> Additionally, they form as an effective barrier to prevent microorganisms from infiltrating a wound.<sup>5,6</sup> Rushbrook et al<sup>5</sup> demonstrated that TAs not only provide a mechanical barrier to bacterial colonization, but also possess intrinsic antibacterial properties. The use of TAs for wound closure have also demonstrated improved cosmetic outcomes compared to standard closure techniques.<sup>3</sup>

As such, the use of TAs as an adjunct in surgical wound closures has become commonplace in orthopedics. Studies have shown that TAs can be used effectively in total hip and knee arthroplasty, oncological surgery, and spine surgery.<sup>4,7-15</sup> While there have been reports of dermatitis and cellulitis after the use of TAs, these are rare.<sup>10,16</sup> In 2020, Kong et al<sup>13</sup> demonstrated that the use of TAs on total hip arthroplasty wounds was associated with significantly reduced postoperative wound drainage and increased patient satisfaction when compared to standard wound closure.

Dermabond (Ethicon, USA) is a commonly used TA composed of 2-octyl cyanoacrylate.

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It is applied as a liquid but undergoes polymerization via an exothermic reaction. To prevent adhesion of surgical dressings to a wound with freshly applied TA, a surgeon or their surgical assistant must wait until the polymerization process has completed. This typically occurs when little else can be done by the surgeon, resulting in an operative 'stand-still.' The goal of our study is to identify a practical method to diminish the reaction time of TAs used as an augment for surgical wound closure.

## Methods

Testing was carried out using Dermabond Mini (Ethicon) 2-octyle cyanoacrylate applicators. Five different methods for decreasing drying time were tested, as well as a control method. Ten TA applicators were allocated to each group for a total of 60 tests. The five methods for decreasing drying time were Fanning, Covering, Operating Room (OR) Lights, Ultraviolet (UV) Light, and Hot Water Bath.

For each testing condition, TA was applied to a 2 × 2 cm area of plexiglass, acting as a reproducible skin substitute. To maintain a consistent thickness and quantity of the TA applied, a scale (Fuzion Digital Milligram Scale, Spain) was used to ensure that between 90 and 105 mg of adhesive was applied. This amount was then spread evenly over the entire surface area. By spreading the same mass of liquid adhesive over a consistent and level surface area, the thickness of the adhesive can be inferred to be even across the entire surface.

The control method involved applying the TA without any subsequent intervention. For Fanning, after the TA was applied, an investigator (IJW) would fan over the TA with their hand in a horizontal orientation until the polymerization process was complete. The Covering technique consisted of creating a dome with a gloved hand over the adhesive until it was deemed dry. The OR Lights condition involved directing two overhead operating room LED lights at the TA from a 30 cm distance. For UV Light, a handheld 395 nm UV flashlight (Aventik Edison Design, China) was held 2 cm from the TA until it was dry. Finally, the Hot Water Bath testing condition consisted of submerging the TA applicator, while still inside its sterile packaging, in a hot water basin kept at 39°C for a minimum of 30 minutes, and removal from the basin just prior to application.

All testing was performed in an operating room, with humidity maintained between 52% and 54% and an ambient temperature between 66.0° and 66.5°F. Testing was performed on top of a pane of plexiglass overlying a patient warming system (Bair Hugger; 3 M, USA) set to 43°C. A level was used to ensure the working surface was not askew, as this could result in pooling of the TA and thus an uneven distribution within the 2 × 2 cm square. A single OR overhead light was maintained on

**Table I.** Comparison of base temperatures to control.

Technique	Mean difference, °F (95% CI)	p-value*
Fanning	-1.31 (-3.2 to 0.6)	0.350
Covering	1.52 (-0.4 to 3.4)	0.199
OR Lights	2.57 (0.6 to 4.5)	0.003
UV Light	-0.91 (-1.0 to 2.8)	0.729
Hot Water Bath	-0.78 (-1.1 to 2.7)	0.837

\*Analysis of variance with post-hoc Tukey's honestly significant difference analysis.

CI, confidence interval; OR, operating room; UV, ultraviolet.

the working surface at a standard distance during all testing except for the OR Lights group.

For each test, the temperature of the work surface was measured using an infrared thermometer. This was reported as the base temperature. A timer was started at the moment of applicator activation. The appropriate weight of TA was applied to the 2 × 2 cm square of plexiglass. This was then transferred to the worksurface, and one of the six testing conditions was then performed until the TA was deemed dry. The time between applicator activation and transfer to the work surface was reported as preparation time, as this was the amount of time needed to weigh and spread the TA before the testing conditions could be applied. The time to complete dryness was determined visually, as TA opacifies as it dries on plexiglass. This time was reported as dry time. As the Covering method occludes visualization, dryness was checked at 1:30, 1:45, 2:00, and then at five-second intervals until deemed dry.

**Statistical analysis.** Statistical analysis was performed in SPSS v. 28 (IBM, USA). Comparisons of base temperature, preparation time, and dry time between the tested methods were performed using analysis of variance testing with post-hoc Tukey's honestly significant difference analysis. Results with p-values < 0.05 were deemed significant.

## Results

Base temperatures for all tests ranged from 81.5°F to 90.1°F. The mean base temperature for the control group was 84.7°F. Compared to the control group, OR Lights had a significantly higher average base temperature (87.4°F (95% confidence interval (CI) 0.6 to 4.5); p = 0.003). There was no significant difference in mean base temperature between the remaining testing groups and the control (Table I).

Preparation time for the tests ranged from 13 to 29 seconds, with a mean time of 20.2 seconds (SD 3.1) (Table II). There was no statistically significant difference in the preparation time between any of the groups (p = 0.318).

Dry times ranged from 1:38 minutes to 3:22 minutes, with the control group having a mean dry time of 2:38 minutes (SD 28 seconds). Compared to the control,

**Table II.** Preparation times per technique.

Technique	Mean preparation time, s (SD)	p-value*
Control	18.4 (4.0)	0.318
Fanning	21.1 (3.5)	
Covering	20.7 (3.2)	
OR Lights	20.7 (1.5)	
UV Light	20.8 (3.2)	
Hot Water Bath	19.3 (3.1)	

\*Analysis of variance with post-hoc Tukey's honestly significant difference analysis.

OR, operating room; SD, standard deviation; UV, ultraviolet.

Covering reduced dry time by a mean of 25 seconds (95% CI 0:00 to 0:51;  $p = 0.042$ ). OR Lights reduced dry time a mean of 27 seconds (95% CI 0:02 to 0:53;  $p = 0.023$ ). Finally, the Hot Water Bath technique reduced dry time by an average of 30 seconds (95% CI 0:05 to 0:56;  $p = 0.009$ ) (Table III). Fanning ( $p = 1.000$ ) and UV Light ( $p = 0.404$ ) had no effect on drying time compared to the control.

## Discussion

Our study found that the Covering, OR Lights, and Hot Water Bath techniques each significantly reduced curing time for TA. While the reduction in curing time may seem clinically insignificant, these techniques are simple to implement and could be easily incorporated into a surgeon's routine to conveniently optimize overall surgical time.

While each of these techniques was effective, they are not without some drawbacks. The Covering technique is limited to smaller surgical wounds that can be covered with a single set of hands, and has a theoretical risk of increasing wound infections. The Hot Water Bath technique requires the use of an intraoperative sterile hot water bath. Additionally, the manufacturer recommends that Dermabond be stored at no greater than 30°C. Thus, the proposed technique exceeds the manufacturer's recommendations for storage. The OR Lights technique is simple and readily available and represents our preferred method for decreasing the curing time of TA. Additionally, while the lights used in this study were LED, and thus produced little heat, institutions using halogen light systems, which produce more heat, may see an even greater increase in adhesive curing time. It is unclear if positioning of OR lights close to the surgical field after application of the adhesive would increase the risk of infection; though it has been shown that OR lights may increase surrounding air bacterial burden when compared to no lights, it remains to be seen if this translates to clinical practice, or if the distance of the lights from the operative field would have any impact.<sup>17</sup>

We attempted to keep the base temperature of the testing field consistent throughout the trials to prevent influence on the observed drying times. Our data did

**Table III.** Comparison of drying times to control.

Technique	Mean difference, mm:ss (95% CI)	p-value*
Fanning	00:02 (-00:23 to 00:27)	1.000
Covering	00:25 (00:00 to 00:51)	0.042
OR Lights	00:27 (00:02 to 00:53)	0.023
UV Light	00:16 (-00:08 to 00:41)	0.404
Hot Water Bath	00:30 (00:05 to 00:56)	0.009

\*Analysis of variance with post-hoc Tukey's honestly significant difference analysis.

CI, confidence interval; OR, operating room; UV, ultraviolet.

show that the OR Lights technique on average had higher base temperatures compared to the control. This is to be expected, given that the proximity of the OR lights heats up the entire testing field. The remainder of the tested methods only affect the TA, rather than the entire field, so there were no effects on base temperature.

We did not observe any effect of UV lights on the drying speed of TA. UV-activated adhesives are common outside the medical industry. The UV light works to cure these adhesives by degrading a photochemical promoter. This process releases free radicals which initiate the adhesive polymerization.<sup>18</sup> While UV-curing adhesives are often acrylates like the 2-octyle cyanoacrylate (Dermabond), to our knowledge Dermabond does not contain the photochemical promoters needed to show a curing response to UV light, and thus an effect was not seen.

While this study was successful in its aims, it was not without limitations. This study only investigated one brand of TA. Additionally, testing was carried out on plexiglass rather than epidermal tissue. Testing on epidermal tissue poses some challenges to standardization of testing, namely in that it prevents precisely weighing out equivalent amounts of TA. Furthermore, testing on skin prevents visually observing the opacification that indicates dryness. Finally, testing on human dermis introduces potential variability in skin porosity, moisture, and temperature. In our proposed setup, we were able to standardize the amount of TA used and the temperature of the testing system. While the actual drying times may be different when TA is applied to epidermal tissue, the relationship of drying time relative to the techniques tested is likely translatable. As such, the testing model used in this study allowed for a highly controlled system which was able to provide information on the relative effects of each methodology. Given that the goal of this study was to compare the effects of each of the proposed drying methods relative to one another, this testing system was successful in its aim.

Our study demonstrated that the Covering, OR Lights, and Hot Water Bath techniques were each effective at reducing the drying time of TA. Given the limitations of the other two methods, we recommend utilizing the OR Lights technique when applying TA to surgical wounds.



### Take home message

- Tissue adhesives are commonly used adjuvants for surgical wound closures.
- Using surgical overhead lights to expedite the curing process of tissue adhesives is a simple and convenient way to optimize surgical workflow.

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